

Temporal, Spatial, and Diurnal Patterns in Avian Activity at the Shuttle Landing Facility, John F. Kennedy Space Center, Florida, U.S.A.

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Abstract

Spatial and temporal patterns in bird abundance within the five-mile airspace at the Shuttle Landing Facility (SLF) on John F. Kennedy Space Center (KSC), Florida, USA were investigated for purposes of quantifying Bird Aircraft Strike Hazards (BASH). The airspace is surrounded by the Merritt Island National Wildlife Refuge (MINWR) which provides habitat for approximately 331 resident and migratory bird species. Avionic operations shared airspace with 74 bird species during the period from February 1993- January 1994. Red-winged Blackbirds, Boat-tailed Grackles, Cattle Egrets, and White Ibis were common year round in the habitats surrounding the runway. Potential bird strike hazards were greatest around sunrise and sunset for most avian taxonomic groups, including wading birds, most raptors, pelicans, gulls/terns, shorebirds, and passerines. Turkey Vultures and Black Vultures were identified as a primary threat to aircraft operations and were represented in 33% of the samples. Diurnal vulture activity varied seasonally with the development of air thermals in the airspace surrounding the SLF. Variation in the presence and abundance of migratory species was shown for American Robins, swallows, and several species of shorebirds. Analyses of bird activities provides for planning of avionics operations during periods of low-risk and allows for risk minimization measures during periods of high-risk.

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INTRODUCTION

Avian activity in and around many airfields poses a serious threat to the safety of aircraft operations. Although birds pose a threat to aircraft flying enroute at high altitudes, the majority of bird strikes occur in the immediate vicinity of airfields where bird densities are higher and aircraft operations are more frequent (Brink 1969, Courtney 1969). Military aircraft are particularly vulnerable to birds because they frequently perform high speed, low altitude maneuvers (DeFusco 1993). Most bird strikes occur below 200 ft (61 m) (Thorpe 1977; van Geuns 1984) and within two miles (3.3 km) of an airfield (Brink 1969).

Birds are attracted to airfields for a variety of reasons. Runways provide relatively safe loafing and roosting areas for species such as gulls, terns, and plovers. Lawns, water retention ponds, and drainage canals provide foraging and nesting sites for grackles, blackbirds, plovers, and other species (Blokpoel 1976). Paved runways may also provide thermals that are utilized by large soaring species such as vultures. Other species that are not attracted to airfields pose hazards by using the airspace above airfields during migration and when traveling between foraging and roosting areas.

Accurate assessment of the bird aircraft strike hazard (BASH) at a particular airfield requires a detailed understanding of the avifauna within the immediate vicinity of the airfield. Regional information such as species ranges, seasonal migratory patterns, and species/habitat associations provide valuable background data; however, local environmental factors may influence species distribution and abundance patterns in ways that cannot be detected at regional levels. Hence, it is critical to quantify temporal (both diurnal and seasonal) (Robbins 1981;

Skirvin 1981) and spatial patterns in avian activity and habitat characteristics specific to the subject airfield.

The Shuttle Landing Facility (SLF) at the John F. Kennedy Space Center (KSC) (Figure 1) is located on Merritt Island National Wildlife Refuge (MINWR). MINWR hosts a high diversity of birds, with 331 species known to occur regularly (MINWR personnel pers. comm.). Several groups of species occur in large numbers. Most notably, from the BASH perspective, are passerines, shorebirds, and Tree Swallows, which occur in large flocks, and single individuals with a large mass such as vultures, wading birds, raptors, ducks, and pelicans. Although the SLF is considered a low-volume airfield, supporting less than 10,000 aircraft operations annually (SLF personnel pers. comm.), its location within MINWR and its proximity to a variety of upland and wetland habitats poses the potential for a significant bird strike hazard.

Aircraft operations at the SLF include space shuttle orbiter landings, shuttle training aircraft missions (STA), passenger and air cargo arrivals and departures, helicopters and private aircraft low approaches. The purpose of this study was to quantify seasonal, diurnal, and spatial patterns in avian activity around the SLF. These data quantify the times and locations where the hazard is highest, and identify species that pose the greatest hazard.

STUDY AREA AND METHODS

The SLF is located on KSC, which is comprised of 57,000 hectares (ha) of land, estuarine waters, and impounded salt and fresh-water marshes. Areas not used by NASA are managed by the U.S. Fish and Wildlife Service (USFWS) as the MINWR and the National Park Service as the Canaveral National Seashore. The SLF consist of a 15,000 x 300 ft (4573 m x 91 m) runway with 1000 ft (305 m) paved over-runs at either end, and associated building

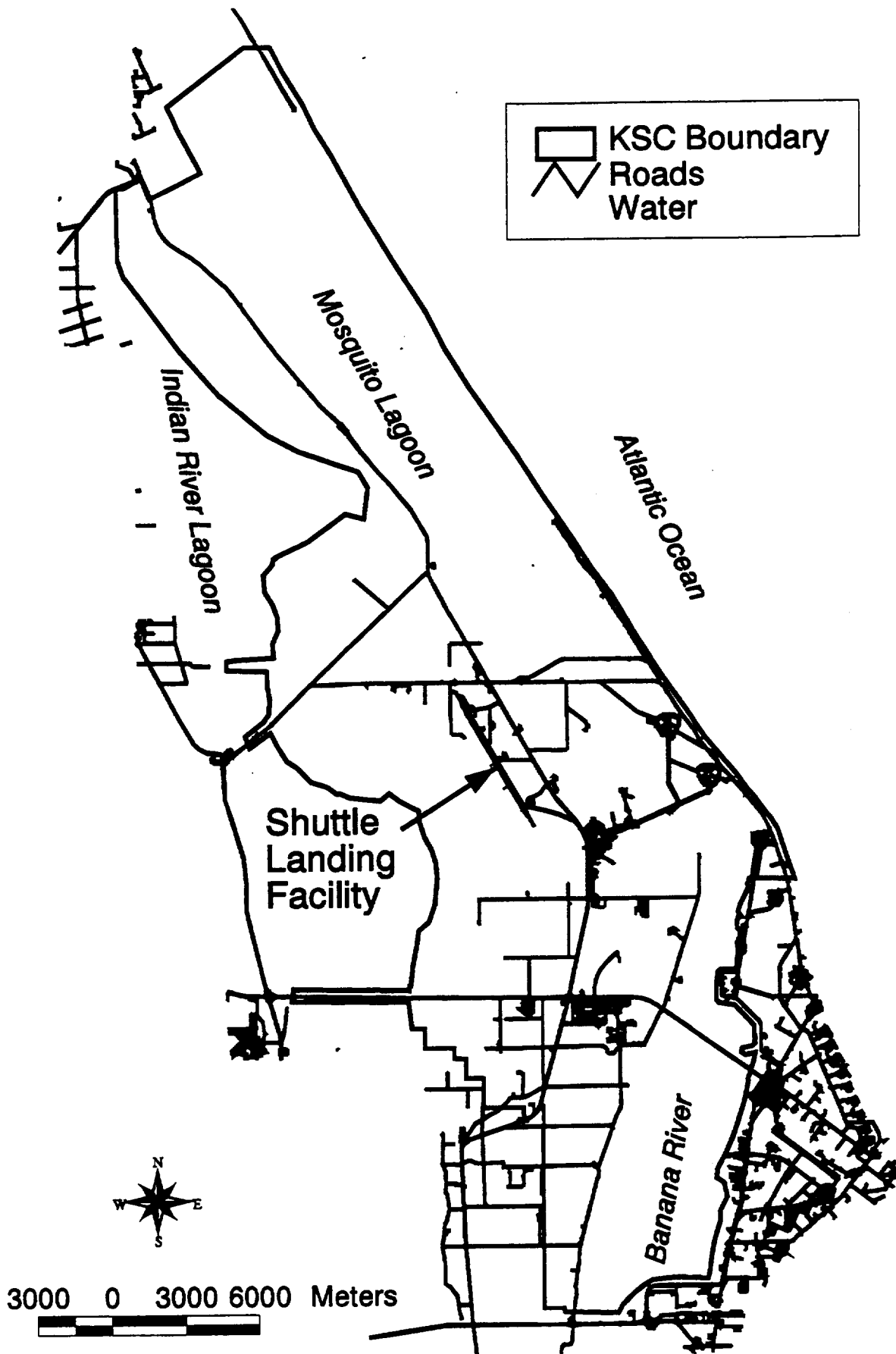


Figure 1. John F. Kennedy Space Center (KSC) and the location of the Shuttle Landing Facility (SLF).

support structures. A 50 ft (15 m) paved shoulder extends the entire length of the runway on either side. Surrounding the runway is a perimeter ditch ranging from approximately 350 ft (107m) to 430 ft (131 m) in width (Figure 2).

The study area included the runway and surrounding maintained grass within the perimeter ditch and extended 7500 ft. (2286 m) to the north and south at the ends of the runway (Figure 2). The areas from 1600 to 3200 ft. (488 to 975 m) beyond each end of the runway were designated high-hazard areas by SLF personnel. Bird activity was sampled at five stations along the runway and two stations in the high-hazard areas. Stations one through five (numbered north to south) were located on the runway. Stations N PAPI and S PAPI were located in the high-hazard areas at the north and south PAPI lights (Figure 2). Consecutively numbered 1,000 ft. markers along the runway served as north/south boundaries for the sampling stations. The centerline of the runway and perimeter ditch served as east/west boundaries, respectively. Prominent landmarks served as boundaries at the N PAPI and S PAPI stations.

At each station the species, number, activity, direction of flight and use of runway, lawn, or airspace of all birds was recorded. Sample duration was ten-minutes. Air temperature, wind speed/direction, and percent cloud cover were recorded at the beginning of each sample. Altitudes of birds within the sample area were estimated and categorized as ground (0 ft), low (≤ 20 ft), medium (21-300 ft), or high (301-1000 ft). Ground and low altitude categories were not used at the N PAPI and S PAPI stations because of the difficulty in accurately recording ground and low-level activity in marsh habitats, and because the stations were located outside of the SLF in areas where aircraft operations occurred only above ca. 100 ft. Biologists periodically calibrated altitude estimations by observing structures of known height and aircraft operations at known altitudes.



Sampling was conducted during daylight hours only, from sunrise until sunset February 1993 through January 1994 . Daylight hours were divided into one-hour periods. Because high variation in avian activity was predicted during the early morning and late afternoon hours (Robbins 1981; Skirvin 1981), the three hours following sunrise and preceding sunset were divided into 1/2 hour periods. Efforts were made to sample of all periods at each station at least once per month. In order to quantify the effects of operational activity on bird activity, sampling included periods of high operational activity (e.g., STA and T-38 operations) and periods of low or no operational activity. To maximize the use of the data, sampling was only conducted in weather conditions most suited for aircraft activity. No sampling was conducted during storms or very high winds.

Because Vultures were specifically identified by the SLF personnel as an aircraft hazard additional vulture activity data was collected. Vulture activity was also quantified by counting the number of vultures using the airspace surrounding the sample station every 15 minutes on the quarter hour. Vulture sampling was conducted opportunistically during bird activity sampling. Only vultures that could be seen without the aid of binoculars were counted.

Data Analysis

Avian species were grouped by taxonomic affiliation and/or habitat associations and behavioral characteristics as: blackbirds, vultures, wading birds, swallows, shorebirds, raptors, gulls/terns, pelican, ducks/rails, Passerines, and others.

Abundance (mean #/sample) and standard deviations were calculated for each of the taxonomic groups by month, station, and time of day. American Robins and Cattle Egrets were analyzed separately because preliminary analyses suggested that activity patterns were distinctly different from other members of their respective taxonomic group. Because vultures generally

wait for the development of thermal activity before leaving their roosts, it was predicted that a shift in the timing of peak vulture activity between winter and summer would occur. Hence, vulture data were separated into two seasons: winter (October-March) and summer (April-September).

Time of day was standardized to sunrise and sunset by dividing the number of daylight hours in each sample day into 12 equal periods, each period being equivalent to 1/12 of the daylight hours. Each sample was grouped into one of the 12 periods.

RESULTS

A total of 74 species were recorded in 1151 samples. Seven species (Boat-tailed Grackle, Turkey Vulture, Red-winged Blackbird, Killdeer, Tree Swallow, White Ibis, Cattle Egret, and Black Vulture) were recorded in at least 10% of the samples (Table 1). Several species (e.g., American Robins and Barn Swallows) were recorded in relatively high abundance, but were present in low frequencies during sampling.

Blackbirds

Grackles and blackbirds were the most frequently observed taxa, being recorded on 40.5% of samples (Table 2). Boat-tailed Grackles and Red-winged Blackbirds were common at all stations (Figure 3) and in all months (Figure 4). Common Grackles were common only at N PAPI where they were seen nesting in willows (*Salix carolinensis*). Boat-tailed Grackles and Red-winged Blackbirds nested in cattails (*Typha* sp.) along the perimeter ditch and foraged in the grass surrounding the runway. Both species were infrequently recorded loafing or foraging on the runway surface individually or in flocks. Ninety percent of grackles and blackbirds that were recorded on the ground used the perimeter grass (Table 3).

Table 1. Frequency of avian species recorded at the Shuttle Landing Facility. Listed in order of frequency of occurrence. Frequency = (No. Samples/ Total No. Samples)x100.

| SPECIES | N | No. Samples | Frequency |
|---|-------|-------------|-----------|
| Boat-tailed Grackle (<i>Quiscalus major</i>) | 1889 | 342 | 29.7 |
| Turkey Vulture (<i>Cathartes aura</i>) | 893 | 338 | 29.4 |
| Red-winged Blackbird (<i>Agelaius phoeniceus</i>) | 1081 | 228 | 19.8 |
| Killdeer (<i>Charadrius vociferus</i>) | 961 | 198 | 17.2 |
| Tree Swallow (<i>Tachycineta bicolor</i>) | 89535 | 186 | 16.2 |
| White Ibis (<i>Eudocimus albus</i>) | 541 | 128 | 11.1 |
| Cattle Egret (<i>Bubulcus ibis</i>) | 327 | 127 | 11.0 |
| Black Vulture (<i>Coragyps atratus</i>) | 366 | 122 | 10.6 |
| Tricolored Heron (<i>Egretta tricolor</i>) | 209 | 103 | 8.9 |
| Snowy Egret (<i>Egretta thula</i>) | 271 | 90 | 7.8 |
| Great Egret (<i>Casmerodias albus</i>) | 123 | 64 | 5.6 |
| Barn Swallow (<i>Hirundo rustica</i>) | 556 | 65 | 5.6 |
| Little Blue Heron (<i>Egretta caerulea</i>) | 96 | 57 | 5.0 |
| Eastern Meadowlark (<i>Sturnella magna</i>) | 150 | 53 | 4.6 |
| Black-bellied Plover (<i>Pluvialis squatarola</i>) | 442 | 45 | 3.9 |
| Glossy Ibis (<i>Plegadis falcinellus</i>) | 157 | 44 | 3.8 |
| American Robin (<i>Turdus migratorius</i>) | 1430 | 43 | 3.7 |
| Osprey (<i>Pandion haliaetus</i>) | 52 | 39 | 3.4 |
| Warbler sp. (<i>Dendroica</i> sp.) | 136 | 37 | 3.2 |
| Common Grackle (<i>Quiscalus quiscula</i>) | 76 | 35 | 3.0 |
| Mourning Dove (<i>Zenaida macroura</i>) | 65 | 33 | 2.9 |
| Great Blue Heron (<i>Ardea herodias</i>) | 30 | 26 | 2.3 |
| Mottled Duck (<i>Anas fulvigula</i>) | 65 | 24 | 2.1 |
| Double-crested Cormorant (<i>Phalacrocorax auritus</i>) | 44 | 22 | 1.9 |
| American Kestrel (<i>Falco sparverius</i>) | 20 | 19 | 1.7 |
| Anhinga (<i>Anhinga anhinga</i>) | 19 | 17 | 1.5 |
| Least Tern (<i>Sterna antillarum</i>) | 222 | 17 | 1.5 |
| Laughing Gull (<i>Larus atricilla</i>) | 32 | 14 | 1.2 |
| Ring-billed Gull (<i>Larus delawarensis</i>) | 14 | 13 | 1.1 |
| Black-necked Stilt (<i>Himantopus mexicanus</i>) | 23 | 11 | 1.0 |
| Vulture sp. | 205 | 12 | 1.0 |
| Wood Stork (<i>Mycteria americana</i>) | 16 | 10 | 0.9 |
| Pileated Woodpecker (<i>Dryocopus pileatus</i>) | 10 | 9 | 0.8 |
| Yellowlegs sp. (<i>Tringa</i> sp.) | 77 | 9 | 0.8 |
| Bald Eagle (<i>Haliaeetus leucocephalus</i>) | 10 | 8 | 0.7 |
| Red-shouldered Hawk (<i>Buteo lineatus</i>) | 14 | 8 | 0.7 |
| Lesser Yellowlegs (<i>Tringa flavipes</i>) | 45 | 8 | 0.7 |
| Yellow-rumped Warbler (<i>Dendroica coronata</i>) | 18 | 8 | 0.7 |
| Green-backed Heron (<i>Butorides striatus</i>) | 7 | 7 | 0.6 |
| Peep sp. (<i>Calidris</i> sp.) | 34 | 7 | 0.6 |

Table 1. (concluded)

| SPECIES | N | No. Samples | Frequency |
|---|----|-------------|-----------|
| Northern Harrier (<i>Circus cyaneus</i>) | 6 | 6 | 0.5 |
| Red-bellied Woodpecker (<i>Melanerpes carolinus</i>) | 7 | 6 | 0.5 |
| Common Moorhen (<i>Gallinula chloropus</i>) | 10 | 6 | 0.5 |
| Common Snipe (<i>Gallinago gallinago</i>) | 14 | 5 | 0.4 |
| Fish Crow (<i>Corvus ossifragus</i>) | 7 | 5 | 0.4 |
| Northern Mockingbird (<i>Mimus polyglottos</i>) | 6 | 5 | 0.4 |
| Common Nighthawk (<i>Chordeiles minor</i>) | 3 | 3 | 0.3 |
| Sharp-shinned Hawk (<i>Accipiter striatus</i>) | 4 | 3 | 0.3 |
| Forster's Tern (<i>Sterna forsteri</i>) | 3 | 3 | 0.3 |
| Northern Flicker (<i>Colaptes auratus</i>) | 3 | 3 | 0.3 |
| Eastern Kingbird (<i>Tyrannus tyrannus</i>) | 12 | 3 | 0.3 |
| Western Sandpiper (<i>Calidris mauri</i>) | 21 | 3 | 0.3 |
| Cedar Waxwing (<i>Bombycilla cedrorum</i>) | 24 | 4 | 0.3 |
| Blue-winged Teal (<i>Anas discors</i>) | 27 | 3 | 0.3 |
| Merlin (<i>Falco columbarius</i>) | 4 | 3 | 0.3 |
| Red-tailed Hawk (<i>Buteo jamaicensis</i>) | 4 | 4 | 0.3 |
| Caspian Tern (<i>Sterna caspia</i>) | 6 | 4 | 0.3 |
| Belted Kingfisher (<i>Ceryle alcyon</i>) | 2 | 2 | 0.2 |
| Greater Yellowlegs (<i>Tringa melanoleuca</i>) | 2 | 2 | 0.2 |
| Blackbird sp. | 5 | 2 | 0.2 |
| Boblink (<i>Dolichonyx oryzivorus</i>) | 4 | 2 | 0.2 |
| Least Sandpiper (<i>Calidris minutilla</i>) | 33 | 2 | 0.2 |
| American Wigeon (<i>Anas americana</i>) | 18 | 2 | 0.2 |
| Black Skimmer (<i>Rynchops niger</i>) | 4 | 2 | 0.2 |
| Royal Tern (<i>Sterna maxima</i>) | 2 | 2 | 0.2 |
| Brown Pelican (<i>Pelecanus occidentalis</i>) | 3 | 2 | 0.2 |
| American Goldfinch (<i>Carpodacus tristis</i>) | 2 | 1 | 0.1 |
| Northern Bobwhite (<i>Colinus virginianus</i>) | 2 | 1 | 0.1 |
| Cooper's Hawk (<i>Accipiter cooperii</i>) | 1 | 1 | 0.1 |
| Gray Kingbird (<i>Tyrannus dominicensis</i>) | 1 | 1 | 0.1 |
| Chimney Swift (<i>Chaetura pelagica</i>) | 1 | 1 | 0.1 |
| Brown Thrasher (<i>Toxostoma rufum</i>) | 1 | 1 | 0.1 |
| Willet (<i>Catoptrophorus semipalmatus</i>) | 1 | 1 | 0.1 |
| Wood Duck (<i>Aix sponsa</i>) | 3 | 1 | 0.1 |
| Northern Pintail (<i>Anas acuta</i>) | 2 | 1 | 0.1 |
| Duck sp. (<i>Anas</i> sp.) | 30 | 1 | 0.1 |
| Dowitcher sp. (<i>Limnodromus</i> sp.) | 5 | 1 | 0.1 |
| Black-crowned Night Heron (<i>Nycticorax nycticorax</i>) | 1 | 1 | 0.1 |
| Roseate Spoonbill (<i>Ajaia ajaja</i>) | 2 | 1 | 0.1 |
| American White Pelican (<i>Pelecanus erythrorhynchos</i>) | 1 | 1 | 0.1 |

N = total # of individuals recorded

Table 2. Frequency of occurrence of avian taxonomic groups at the Shuttle Landing Facility. Listed in order of frequency of occurrence. Frequency = (No. Samples/ Total No. Samples)x100.

| TAXONOMIC GROUP | N | No. Samples | Frequency |
|-----------------|-------|-------------|-----------|
| Blackbirds | 3051 | 466 | 40.5 |
| Vultures | 1464 | 381 | 33.1 |
| Wading Birds | 1453 | 336 | 29.2 |
| Swallows | 90141 | 247 | 21.5 |
| Shorebirds | 442 | 239 | 20.8 |
| Passerines | 426 | 142 | 12.3 |
| Cattle Egret | 327 | 127 | 11.0 |
| Raptors | 120 | 84 | 7.3 |
| Gulls/Terns | 283 | 51 | 4.4 |
| American Robin | 1430 | 43 | 3.7 |
| Pelicans | 167 | 42 | 3.6 |
| Ducks | 155 | 37 | 3.2 |
| Other | 28 | 24 | 2.1 |

N = total # of individuals recorded

Table 3. Frequency of taxonomic groups using the runway and grass (0 ft) at the Shuttle Landing Facility. Frequency = (No. Samples/ Total No. Samples)x100.

| Species/Group | N | Frequency | |
|----------------|------|-----------|-------|
| | | Runway | Grass |
| American Robin | 433 | 0 | 100 |
| Cattle Egret | 225 | 0 | 100 |
| Wading Birds | 191 | 0 | 100 |
| Blackbirds | 1123 | 10.1 | 89.9 |
| Raptors | 8 | 25 | 75 |
| Vultures | 22 | 40.9 | 59.1 |
| Plovers | 1065 | 79.4 | 20.6 |
| Swallows | 241 | 100 | 0 |
| Terns/Gulls | 37 | 100 | 0 |

N = total # of individuals using ground surface

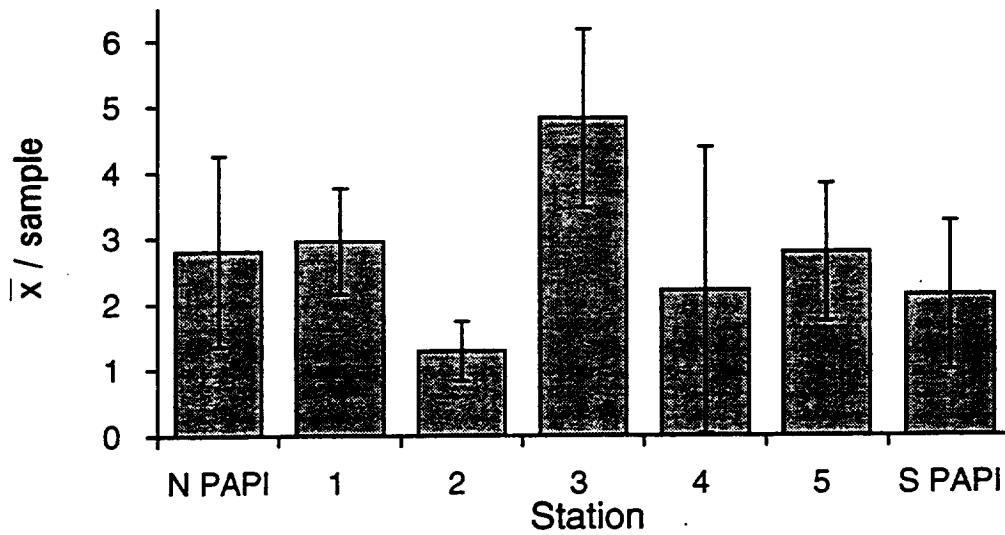


Figure 3. Blackbird abundance (mean #/ sample) at stations 1-5, N PAPI, and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

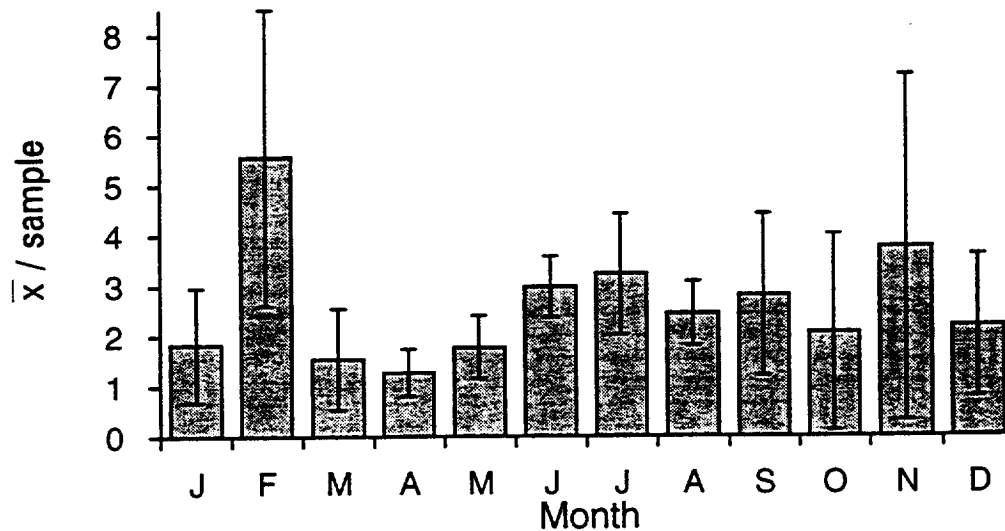


Figure 4. Monthly blackbird abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

Grackles and blackbirds were rarely recorded flying above low altitude except at N and S PAPI where most individuals were recorded flying below ca. 50 ft (Figure 5). At stations one through five individuals often crossed the runway when traveling between foraging and nesting areas. During the breeding season (February/March - June/July) grackles and blackbirds were most commonly seen individually or in small groups; however, mixed species foraging flocks of up to ca. 100 individuals were common during the late summer and winter. Blackbird activity was highest in the early morning from sunrise to ca. one hour after sunrise and in late afternoon from ca. one hour before sunset to sunset (Figure 6). During these periods blackbirds and grackles were most often recorded foraging in the perimeter grass.

Wading Birds

White Ibis and Cattle Egrets were the most abundant and most frequently recorded wading birds and were the only wading birds recorded in at least 10% of samples (Table 1). Overall wading bird abundance increased from north to south with the exception of N PAPI, where abundance was higher than all but station five and S PAPI (Figure 7). Cattle Egrets exhibited a distinctly different pattern from all other wading birds observed: Cattle Egrets were most abundant at stations one through five along the runway and least abundant at N PAPI and S PAPI (Figure 7).

Wading birds were observed in all months and showed no clear seasonal abundance patterns (Figure 8). Cattle Egrets are permanent residents at KSC, however, a large part of the population migrates south during the winter (Robertson and Woolfenden 1992). Hence, Cattle Egrets showed a distinct seasonal pattern, and although they were recorded in small numbers in the winter months, they were common from May through September (Figure 8).

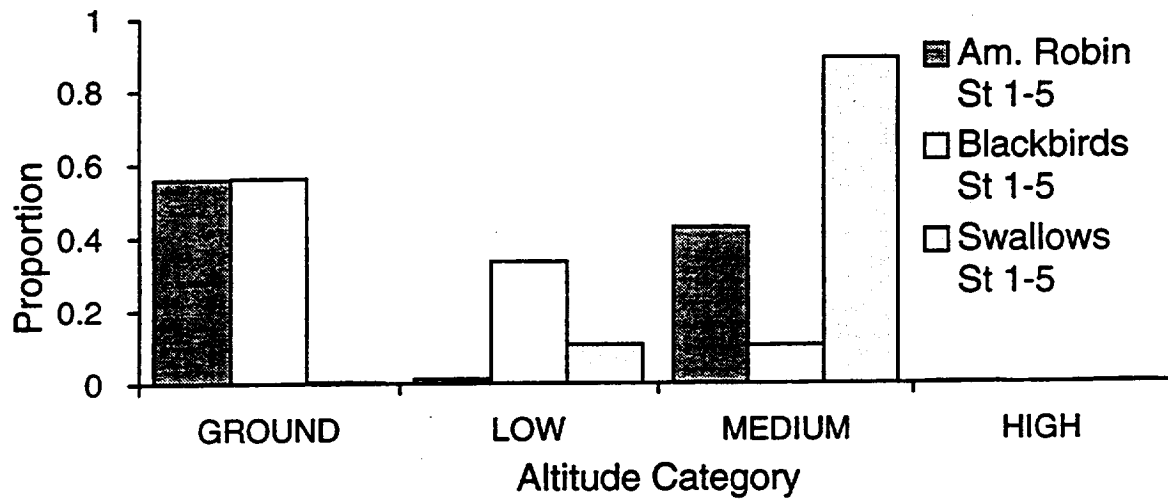


Figure 5. Altitudinal distribution of American Robins, Blackbirds, and Swallows shown as proportion. Ground = runway or grass surface; Low = <20 ft; Medium = 21-300ft; High 301-1000 ft. St = Stations along runway.

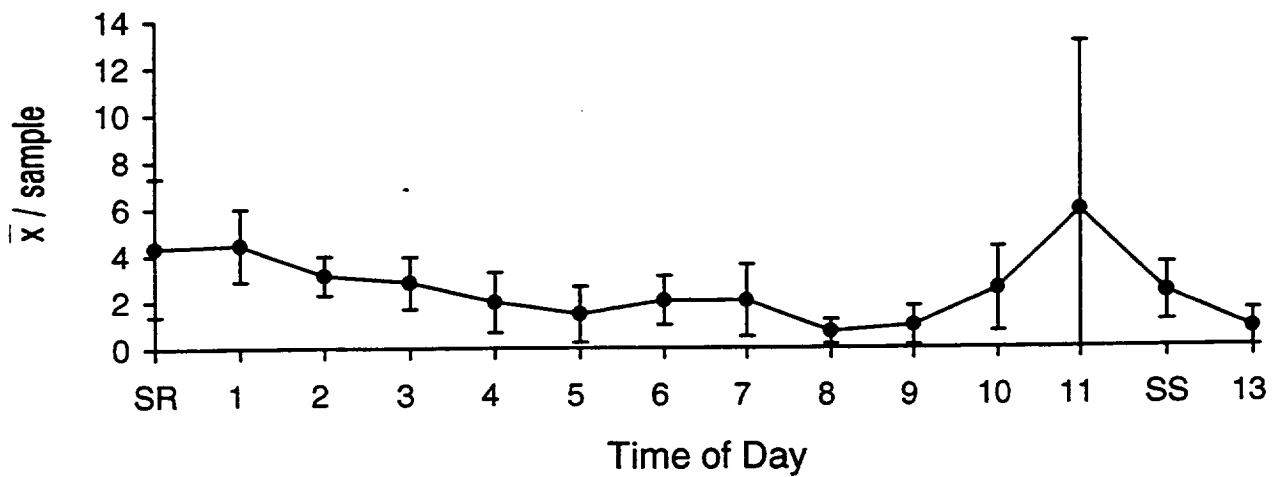


Figure 6. Diurnal blackbird abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

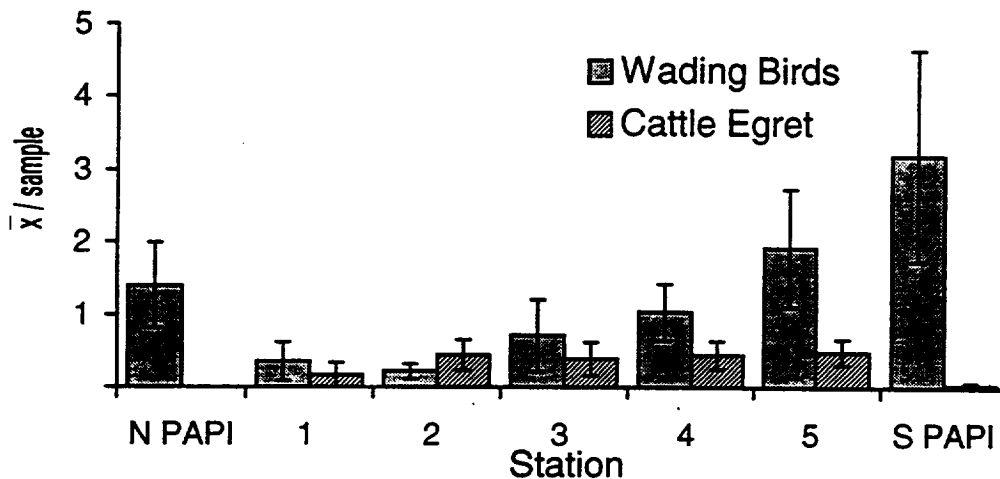


Figure 7. Wading bird and Cattle Egret abundance (mean #/ sample) at Stations 1-5, N PAPI, and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

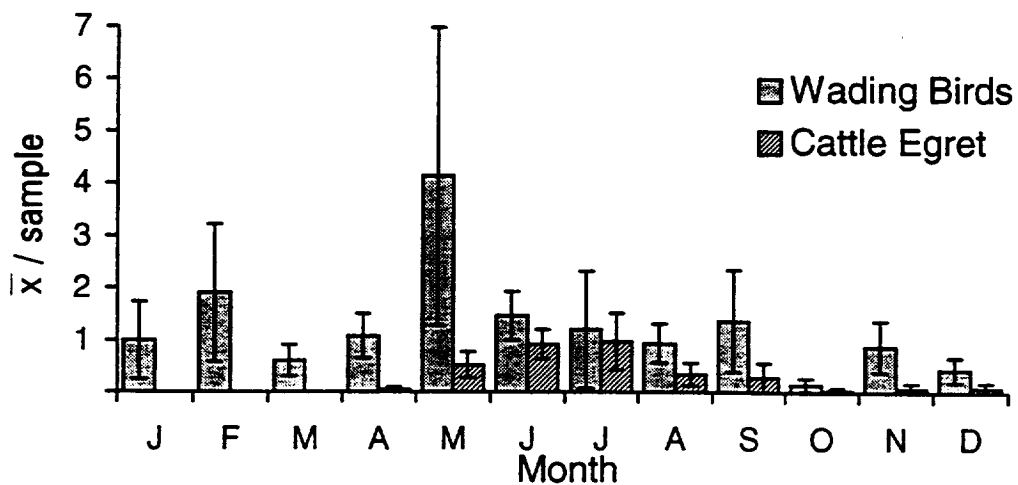


Figure 8. Monthly wading bird and Cattle Egret abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

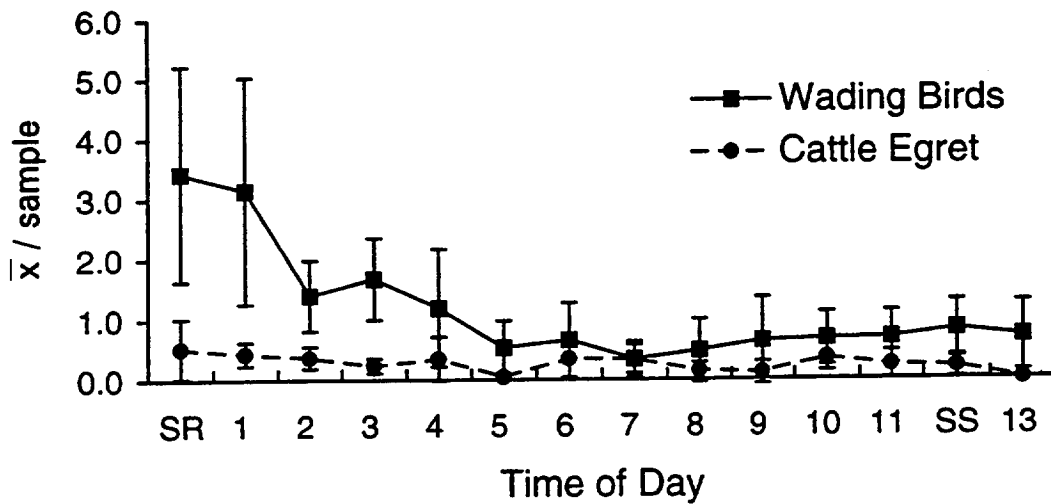


Figure 9. Diurnal wading bird and Cattle Egret abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

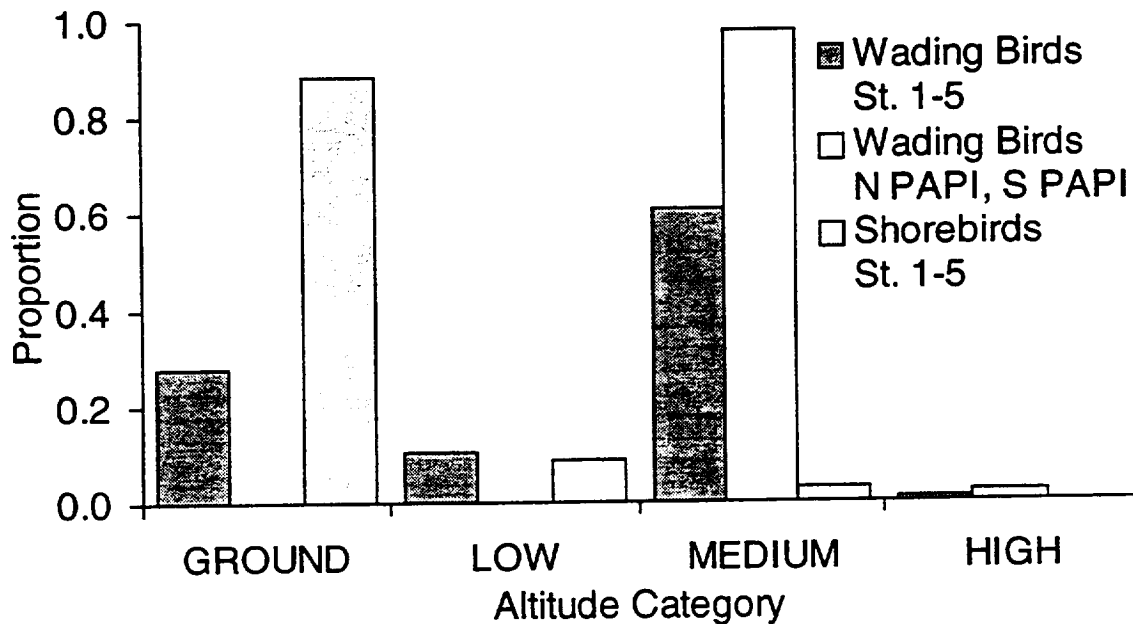


Figure 10. Altitudinal distribution of wading birds and shorebirds shown as proportion. Ground = runway or grass surface; Low = <20 ft; Medium = 21-300 ft; High = 301-1000 ft, St. = Station.

Wading bird activity peaked ca. one hour after sunrise (Figure 9) when individuals and small flocks were commonly seen flying over the runway and PAPI lights, traveling between roosts and foraging areas. Cattle Egrets showed no discernible pattern in timing of diurnal activity.

Wading birds were most commonly observed flying at medium altitudes (21-300 ft) (Figure 10). Cattle Egrets and White Ibis were most often seen foraging in small (<20 individuals) flocks on the perimeter lawn. Cattle Egrets often foraged behind lawn mowers that were cutting grass around the SLF.

Vultures

Data from instantaneous vulture counts reveal a strong north/south trend in vulture abundance (Figure 11). Data from 10-minute sample periods showed only a slight north/south trend (Figure 12). These data consisted only of vultures that flew through SLF airspace within the bounds of the sample station, whereas data from instantaneous counts included all vultures that could be seen flying in the vicinity of the SLF without the aid of binoculars. This apparent discrepancy between data sets suggests that although vulture abundance increased from north to south, vultures did not necessarily use the airspace above the SLF any more at the south end with the possible exception of S PAPI.

A large (ca. 500 individuals) mixed species vulture roost was located near the northeast corner of S PAPI. Vultures departing from this roost accounted for a large proportion of the early morning vulture activity recorded. Several other smaller roosts were located in other areas around the SLF; however, these roosts accounted for a smaller percentage of the number of vultures using the airspace in the vicinity of the SLF.

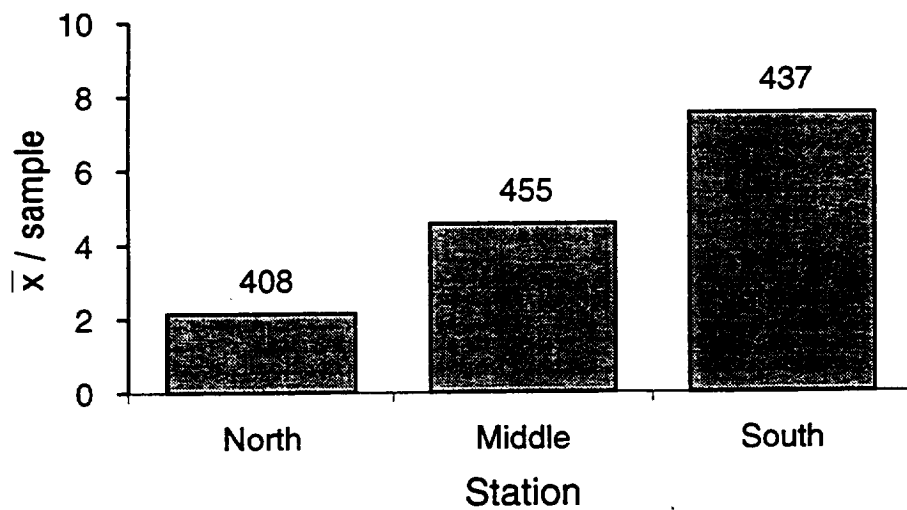


Figure 11. Vulture abundance (mean #/ sample) by station from instantaneous counts. North = N PAPI and Station 1; Middle = Stations 2, 3, and 4; South = Stations 5 and S PAPI. Values on bars indicate sample size.

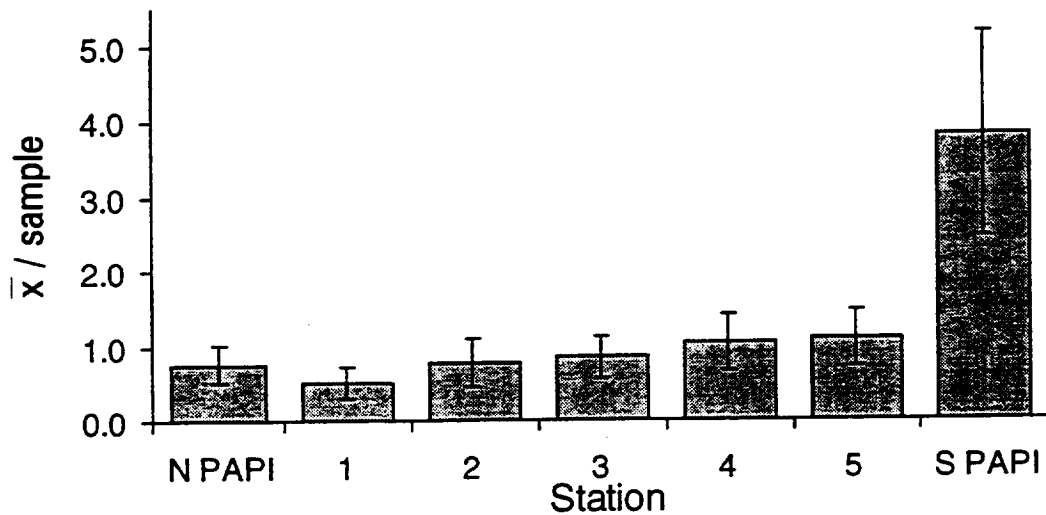


Figure 12. Vulture abundance (mean #/ sample) from 10 minute counts at Stations 1-5, N PAPI and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown Appendix A.

Vultures are permanent residents at KSC and were common in all months (Figure 13). No clear seasonal patterns were evident in either data set. Vulture abundance peaked ca. 2-3 hours after sunrise (Figure 14), when vultures typically left roosts in flocks of up to ca. 200 individuals. During the summer, timing of vultures departing roosts was highly synchronous. Frequently, all vultures departed from the roost within a period of less than 1/2 hour. This activity resulted in a strong peak in activity at ca. three hours after sunrise followed by a rapid decrease in activity until ca. mid-day (Figure 14). During winter months, timing of vultures leaving roosts was less synchronous. Vultures frequently departed roosts in small flocks of several individuals. Often the time between the first and last flocks leaving the roost was several hours. This activity resulted in a broader peak in activity that remained considerably lower than what was seen during the summer months (Figures 15 and 16). Peak activity in winter occurred ca. mid-day.

Timing of vulture activity varied with location. Activity at the northern two stations peaked ca. mid-day in both summer and winter (Figures 15 and 16). Peak activity was delayed at the north and middle stations, and the magnitude of the peak approached only the lowest activity periods recorded at the southern most stations (Station 5 and S PAPI).

Vultures leaving roosts attained high altitudes and dispersed quickly. Activity declined by late-morning and remained highly variable throughout the day. A slight increase in activity occurred ca. two hours before sunset as vultures returned to their nightly roosts. Vultures generally returned to roosts by active flight at medium altitudes just above the forest canopy or by soaring to roosts from the Vehicle Assembly Building (VAB) where large numbers often congregated on up-welling air currents.

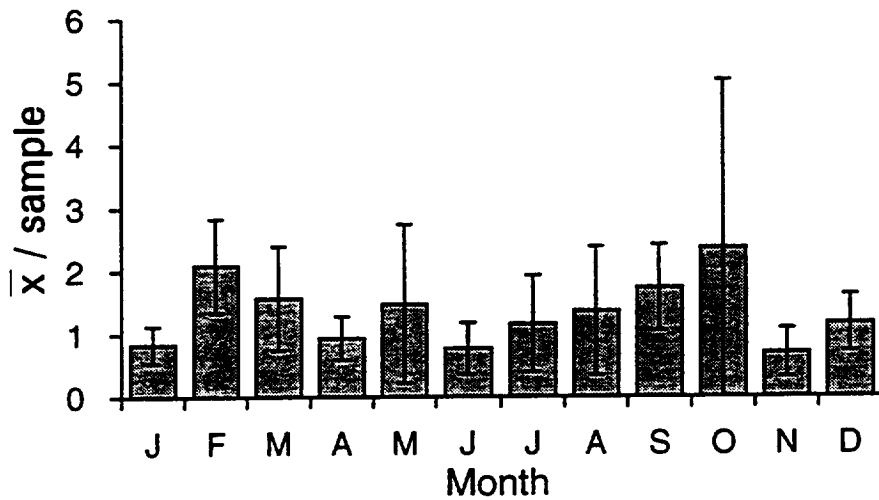


Figure 13. Monthly vultures abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

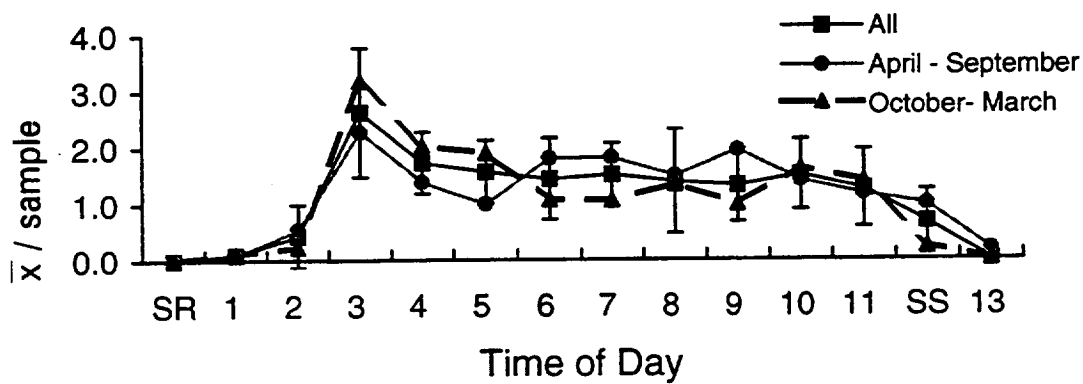


Figure 14. Diurnal vulture abundance (mean #/ sample). Error bars show 95% confidence interval for all vultures. Means, standard deviations and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

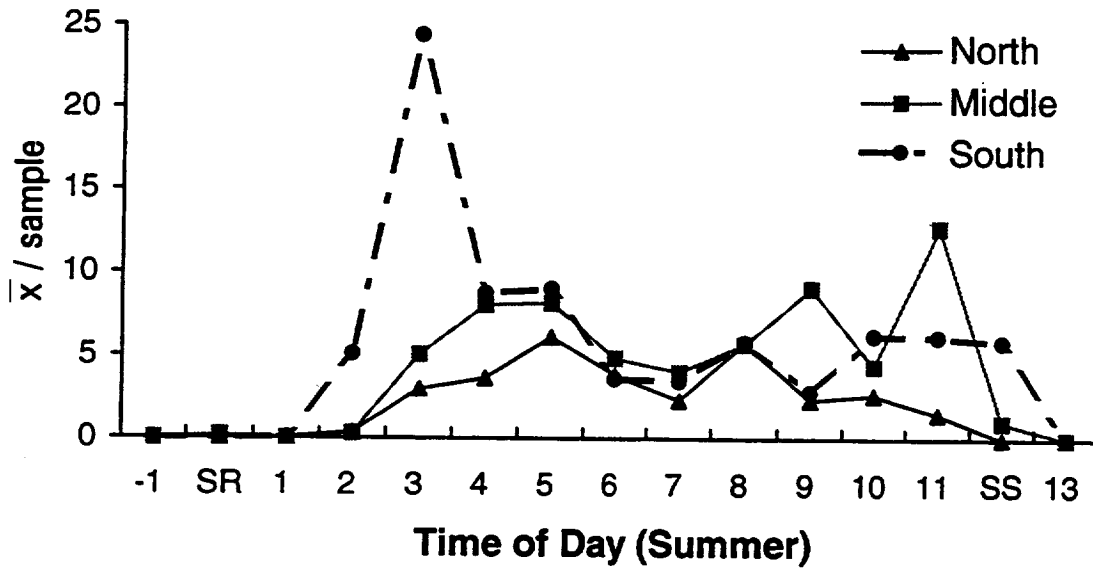


Figure 15. Diurnal vulture abundance (mean #/ sample) for three regions of the Shuttle Landing Facility from April to September. SR = sunrise; SS = sunset.

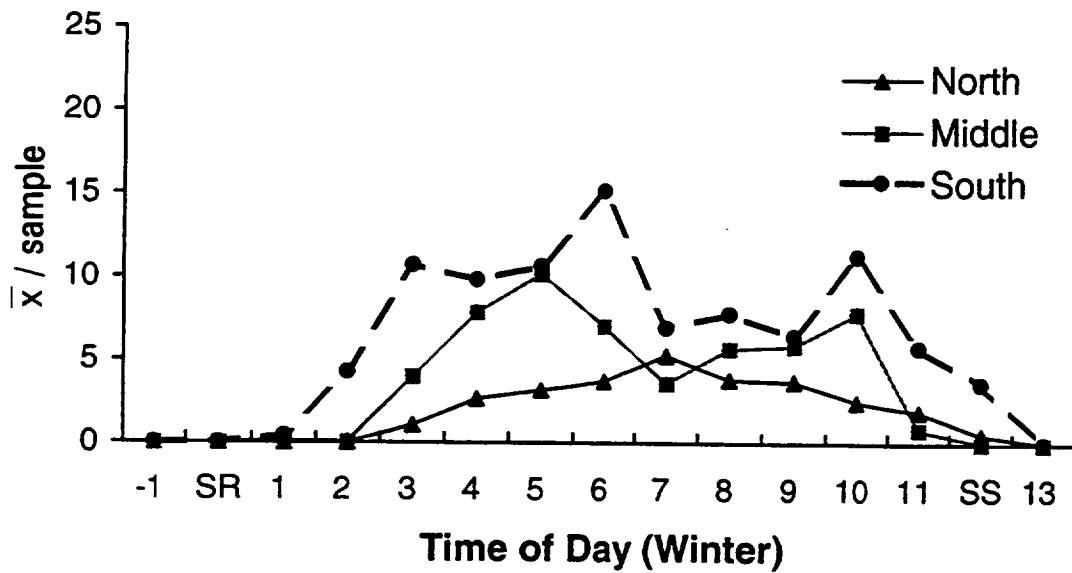


Figure 16. Diurnal vulture abundance (mean #/ sample) for three regions of the Shuttle Landing Facility from October to March. SR = sunrise; SS = sunset.

Overall, vultures were most frequently recorded soaring at medium and high altitudes (Figure 17). January through May, 70 to 80% of all vultures were recorded at high altitudes; however, during June through December their altitudinal distribution became quite variable (Figure 18). Vultures were often seen roosting on the perimeter fence and occasionally were recorded loafing on the runway surface or perimeter grass (Table 3).

Swallows

Two species of swallows, Tree Swallows and Barn Swallows, were observed during this study (Table 1). Greater than 90,000 Tree Swallows, were counted, making Tree Swallows the most abundant of all species or taxonomic group recorded. Swallows showed no apparent north/south trend (Figure 19). Abundance was significantly lower at N PAPI than at all other stations. Tree Swallow abundance was highest at stations one and two; however, this is due to one exceptionally large flock ca. 250,000 individuals that frequented the vicinity of the SLF in March 1993.

Tree Swallows are migrant and winter residents at KSC. Barn Swallows are spring and fall migrants, wintering outside of the U.S. This seasonality is shown in Figure 20. Tree Swallows were recorded October through April. Barn Swallows were recorded only in the spring (April and May) and fall (August and September).

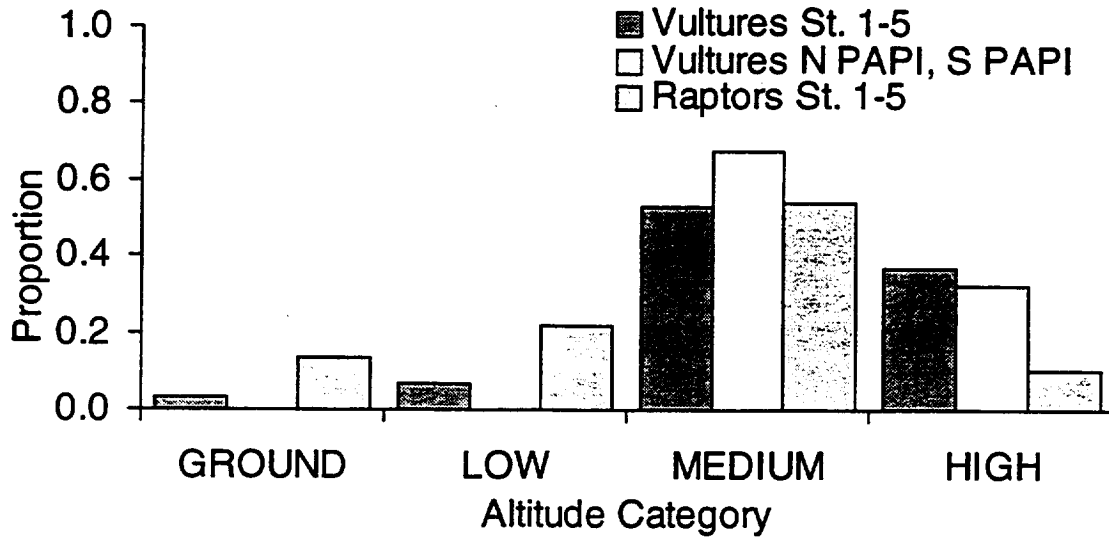


Figure 17. The proportion of vultures and raptors found at different altitudinal classes along the runway (St. 1-5) and at the overruns (N PAPI and S PAPI). Ground = runway or grass surface; Low = <20 ft; Medium = 21-300 ft; High = 301-1000 ft.

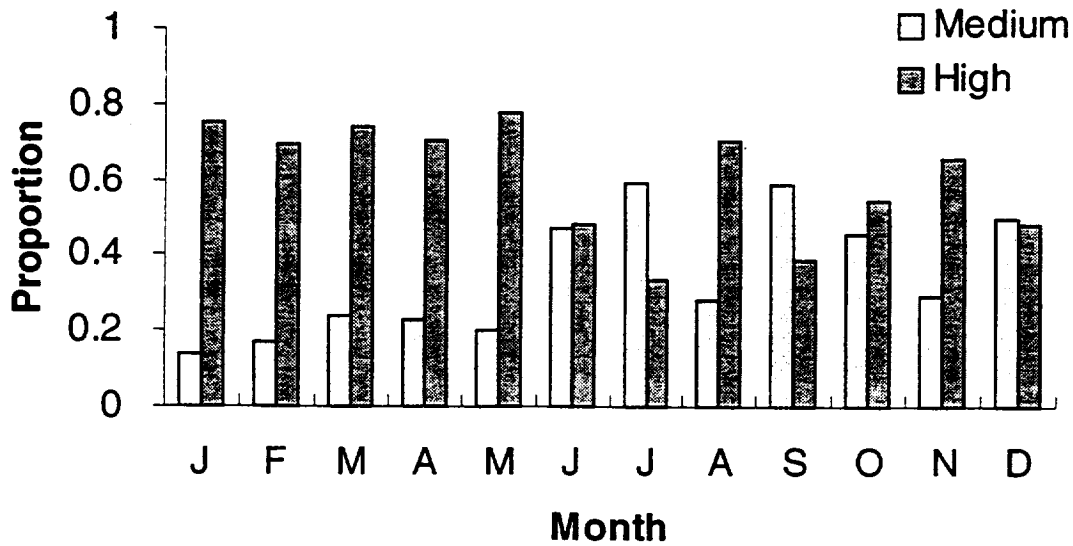


Figure 18. The monthly proportion of vultures occupying medium (21-300 ft) and high (301-1000 ft) altitudes near the Shuttle Landing Facility.

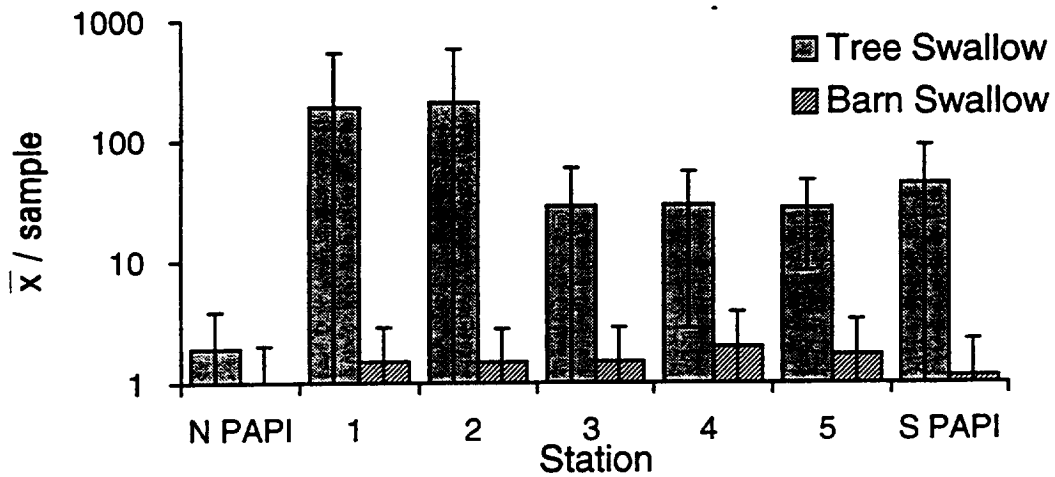


Figure 19. Tree Swallow and Barn Swallows abundance (mean #/ sample) at stations 1-5, N PAPI, and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

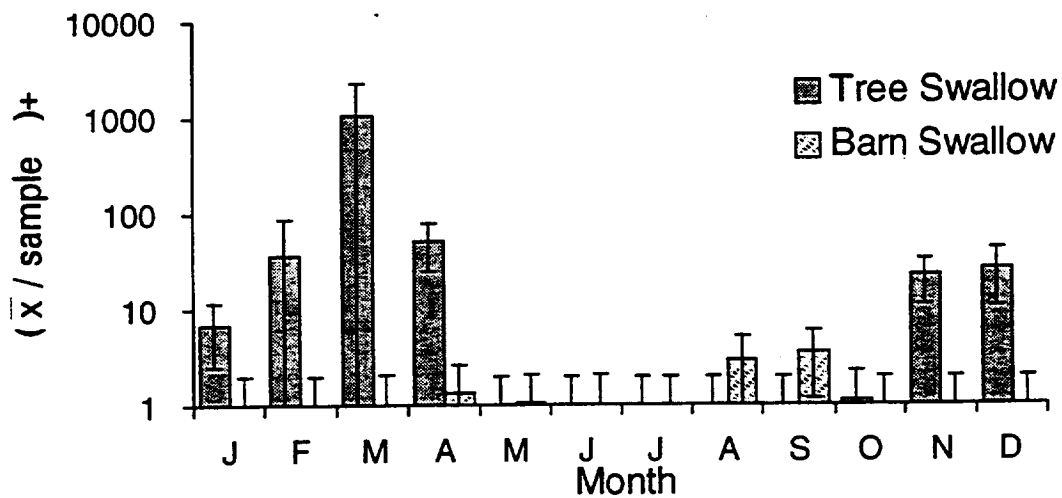


Figure 20. Monthly Tree Swallow and Barn Swallow abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

Greater than 90% of all swallows were recorded flying at medium altitudes (Figure 5).

Tree Swallows foraged on wax-myrtle (*Myrica cerifera*) fruit near the SLF and on insects over the perimeter ditch, lawn, and runway. They were frequently recorded in large dense flocks of up to ca. 20,000 individuals. These flocks frequently were seen within the vicinity of the SLF for several days at a time, often foraging over the runway. Barn Swallows activity peaked ca. four hours after sunrise then dropped to a low ca. mid-day (Figure 21).

Shorebirds

A total of 13 species of shorebirds were recorded (Table 1); however, Killdeer and Black-bellied Plovers were the only two species that regularly occurred at stations one through five. Killdeer were present year-round and nested in the perimeter grass in small numbers. Shorebirds showed no obvious north/south trend (Figure 22), but they were considerably less abundant at N PAPI than at any of the runway stations or S PAPI. Shorebird abundance was highest at station one where Black-bellied Plovers and Killdeer were observed loafing in flocks of ca. 50 individuals.

Shorebirds were present during all study months. Abundance was highest in January and February and lowest May through July (Figure 23). Six of the 13 shorebirds species recorded were winter residents. Black-necked Stilts, Willets and Killdeer, were present year-round; however, nearly all of the shorebirds recorded during the summer months (May through July) were Killdeer that nested in grass or gravel areas surrounding the SLF.

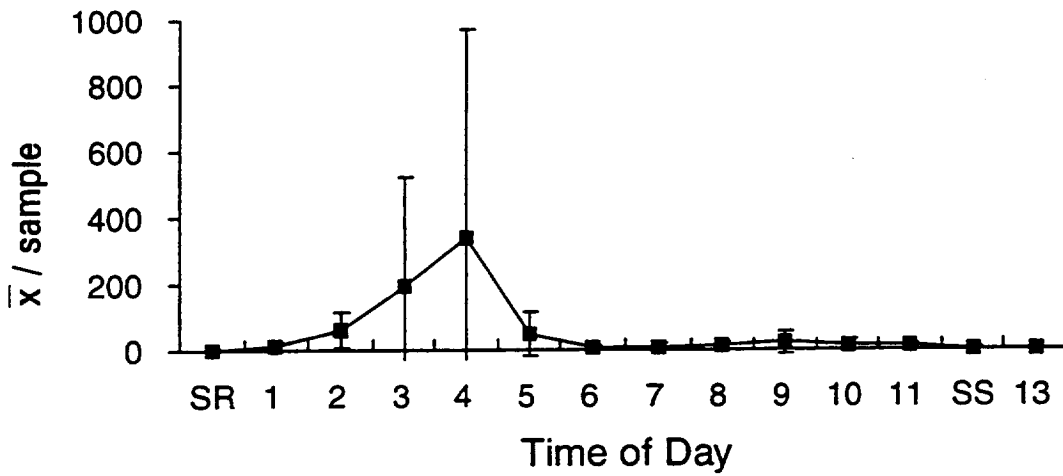


Figure 21. Diurnal swallow abundance (mean #/ sample). Error bars show 95% confidence interval. Means standard, deviations and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

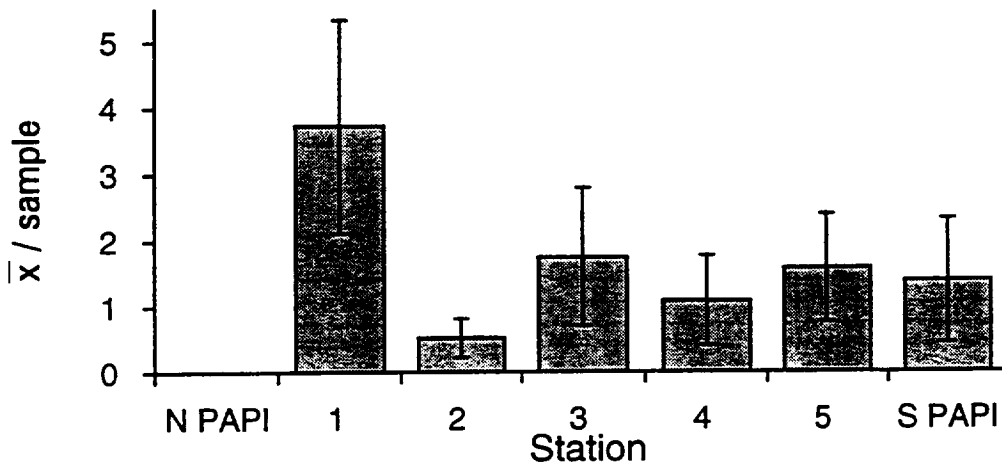


Figure 22. Shorebird abundance (mean #/ sample) at Stations 1-5, N PAPI and S PAPI. Means, standard deviations, and sample sizes are shown in Appendix A.

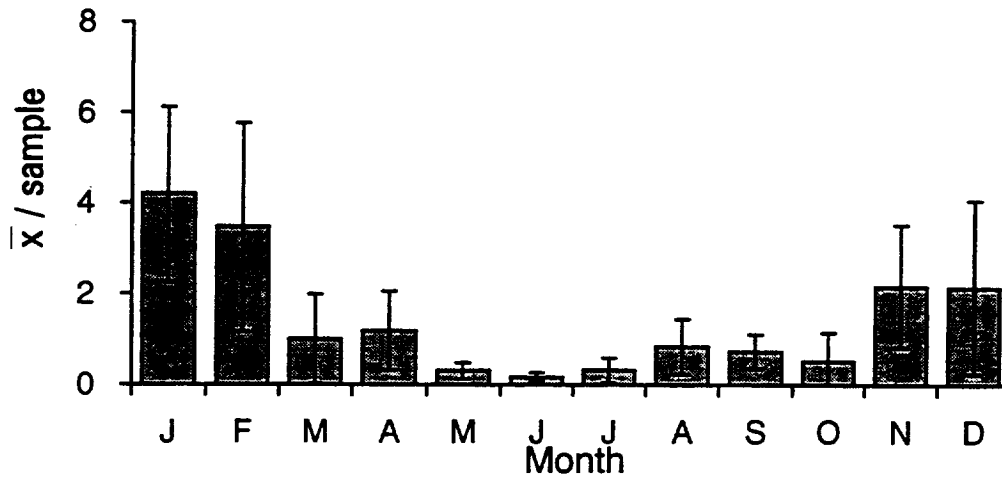


Figure 23. Monthly shorebirds abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

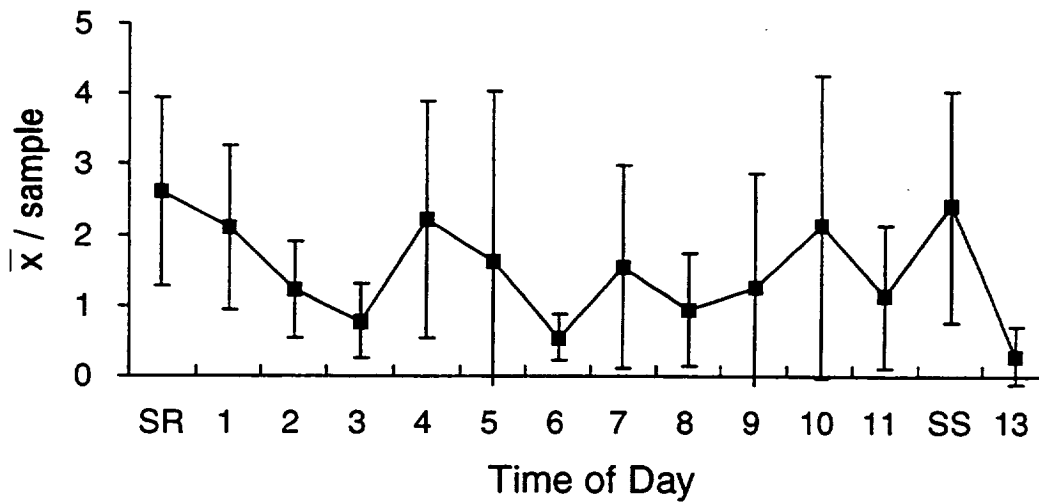


Figure 24. Diurnal shorebird abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

Nearly 90% of shorebird activity at stations one through five were observed on the ground (Figure 10). Of these recorded, ca. 80% were recorded loafing on the runway (Table 3). Shorebird activity was highly variable and demonstrated no clear diurnal patterns (Figure 24). Black-bellied Plovers and Killdeer were often seen on the runway before sunrise and before sunset, suggesting that they remained on the runway throughout the night.

American Robins

American Robins were analyzed separately from other passerines because large flocks of robins present a potential hazard and because robin activity patterns were distinctly different from all other related species. Robins were most abundant at N PAPI and station one (Figure 25), however, robins were observed in relatively low-frequency (Table 1). Robins are migrants and winter residents on KSC and were recorded November through March (Figure 26). Abundance peaked in February; however, this peak is largely a result of a single large foraging flock at station one in February 1993.

Robins exhibited a strong diurnal trend in activity. Activity peaked at ca. sunrise and declined steadily to a low at ca. mid-day (Figure 27). A smaller peak in activity occurred at ca. four hours before sunset, and may be the result of evening foraging activity. This peak may follow the diurnal activity patterns of many invertebrates in the grass and other vegetation surrounding the SLF. Robins were most commonly recorded flying over N PAPI at medium altitudes (Figure 5), below ca. 50 ft, and foraging in the grass surrounding the runway. Robins were never recorded loafing on the runway (Table 3). On several occasions Robins were seen foraging in the perimeter grass before sampling began at sunrise, but Robins were never recorded on the runway at or after sunset. Hence, Robins most likely roosted away from the SLF and arrived to forage before sunrise.

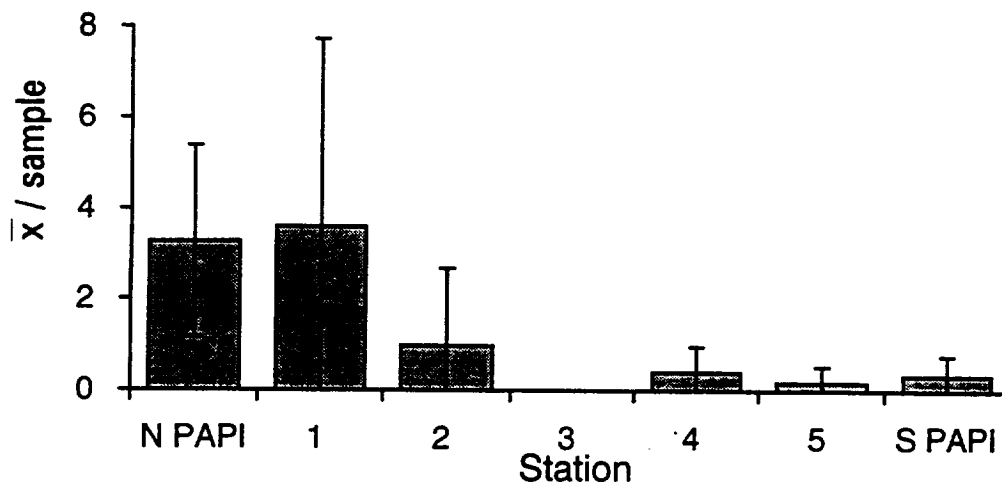


Figure 25. American Robin abundance (mean #/ sample) at stations 1-5, N PAPI and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

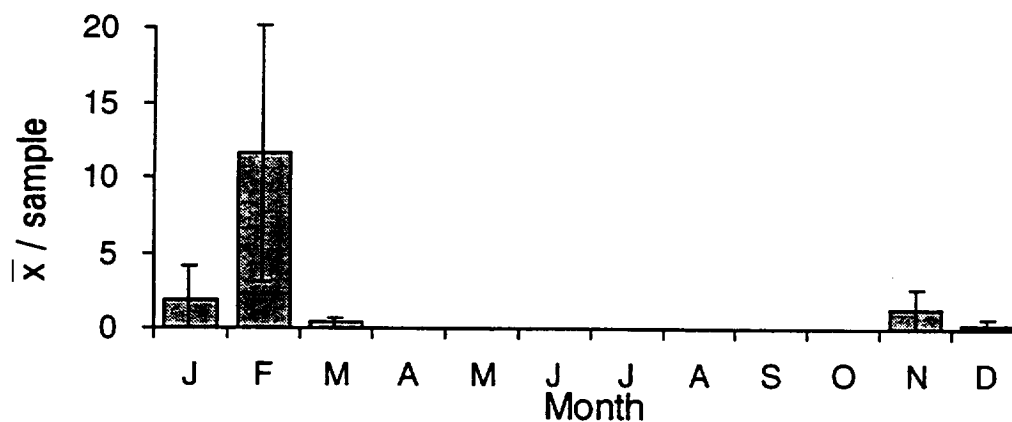


Figure 26. Monthly American Robin abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

Miscellaneous Taxa

Passerines were represented in 12.3% of all samples. Abundance was highest at the N PAPI (Figure 28) where small unidentified *Dendroica* spp. (probably Yellow-rumped Warblers) were often observed flying across the station from one hammock to another. Other passerines observed at the SLF included the Eastern Meadowlark, Mourning Dove and others (Table 1). Passerines were most abundant during the winter months January through March (Figure 29), which correlates with over-wintering populations of migrants.

Raptors were represented in 7.3% of all samples. Ospreys were the most commonly recorded raptors (39 samples). Ospreys were occasionally seen foraging over the perimeter ditch; however, the majority of observations were recorded at S PAPI where Ospreys commonly foraged over the impounded marshes or Banana Creek (Figure 30). Ospreys were observed during all study months (Figure 31). Activity periods were highest in the months of March and September.

Gulls and terns were recorded in moderate abundance, although, they occurred in only 51 (4.4%) samples. During the months of April through August, Least Terns were occasionally recorded at station five loafing on the runway surface in flocks of ca. 30 individuals. Least Terns were observed in 17 samples representing a total of 222 individuals making them the most abundant and most frequent of all gulls and terns. Laughing Gulls and Ring-billed Gulls were occasionally observed flying over the runway or foraging over the impoundments at S PAPI. All other species of gulls and terns were infrequently recorded and were usually associated with loafing flocks of Least Terns.

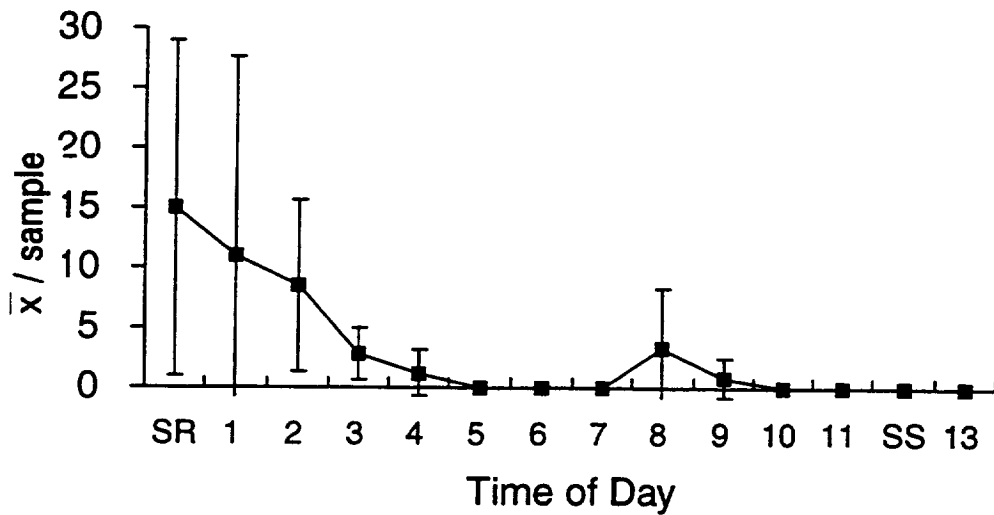


Figure 27. Diurnal American Robin abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix C. SR = sunrise; SS = sunset.

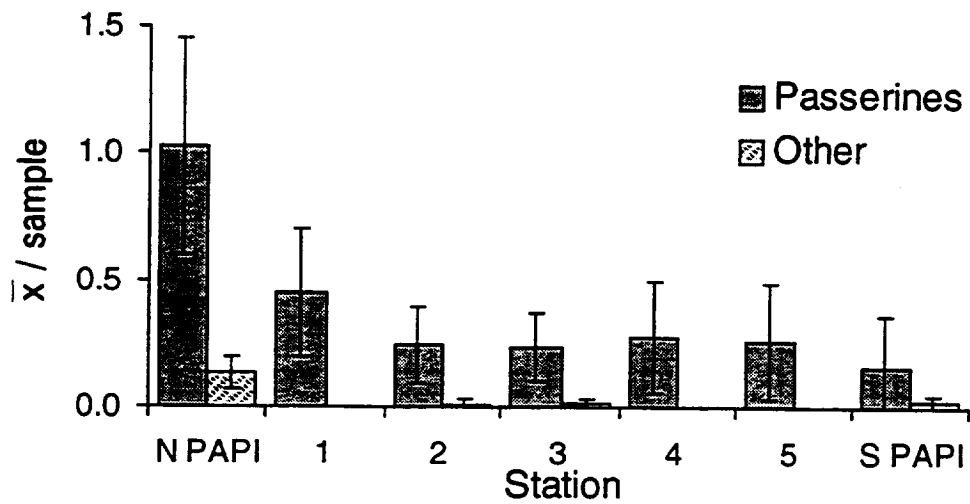


Figure 28. Passerine and other avian species abundance (mean #/ sample) at Stations 1-5, N PAPI, and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

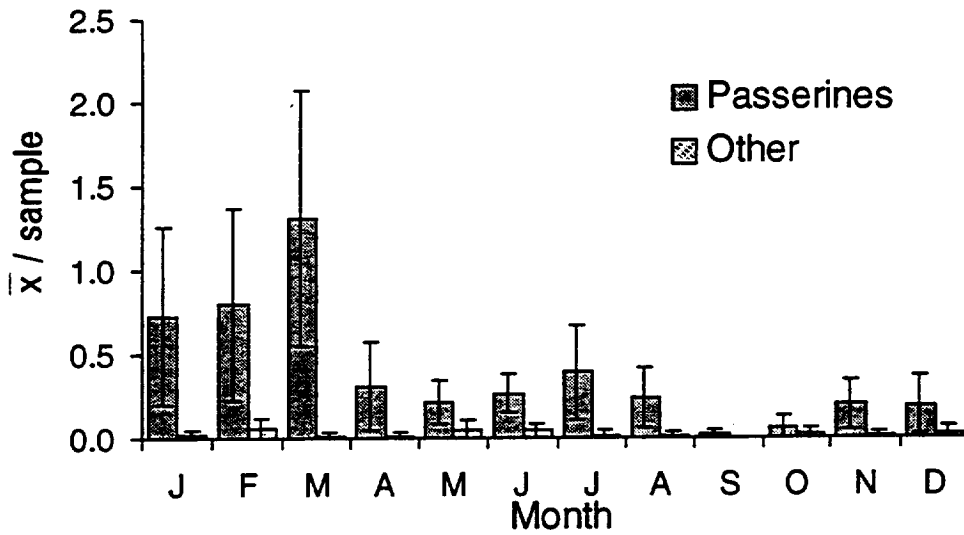


Figure 29. Monthly passerines and other avian species abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

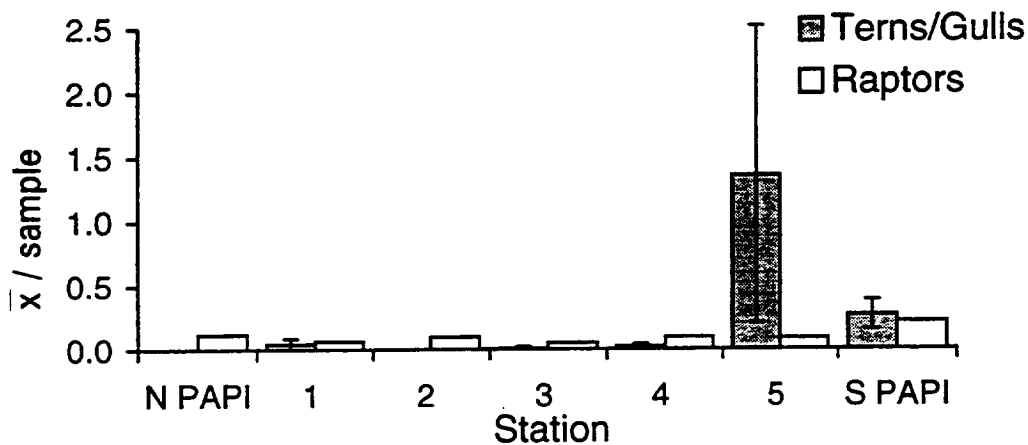


Figure 30. Tern/gull and raptor abundance (mean #/ sample) at Stations 1-5, N PAPI, and S PAPI. Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix A.

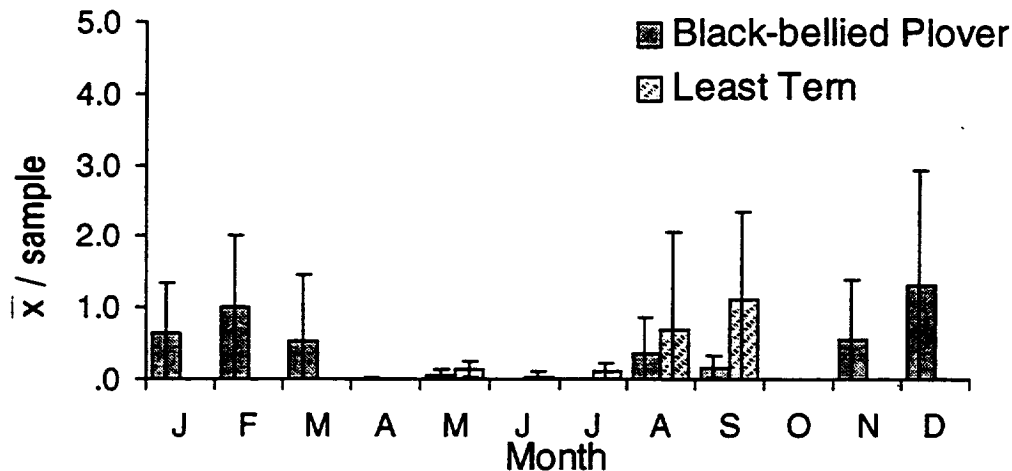


Figure 31. Monthly Black-Bellied Plover and Least Tern abundance (mean #/ sample). Error bars show 95% confidence interval. Means, standard deviations, and sample sizes are shown in Appendix B.

Pelicans, Anhingas, and Double-crested Cormorants were represented in 42 (3.6%) samples. The majority of sightings were of Double-crested Cormorants and Anhingas (22 and 17 samples respectively) flying at medium altitudes over S PAPI. Brown Pelicans were often seen foraging over the Banana Creek; however, they were recorded in only two samples.

Ducks were recorded in 37 samples (3.2%). Mottled Ducks were the most frequently recorded duck [24 samples (2.1%)]. All Mottled Duck records were from S PAPI where they foraged in impoundments and were recorded flying at medium altitudes between foraging areas. All other duck species were recorded in small numbers with the exception of a flock of about 30 (species unidentified) flying high over station four in April 1993.

DISCUSSION

The location of the Shuttle Landing Facility (SLF) within the MINWR makes it a particularly attractive area for avian activity. The SLF's approximate north-south orientation traverses many natural community types including open lagoon waters and impoundments on the south, oak scrub and freshwater swales near the middle, and hammocks and shrub marshes on the north. Each community type has an association of avian species which may influence aircraft operations. Because most aircraft approach the SLF at high speeds, usually as a part of training operations, the airspace from 1600 to 3200 ft (488 to 975 m) from the ends of the runway at altitudes of 300 to 1000 ft are designated hazard areas for Bird Aircraft Strike Hazards (BASH). Shuttle Training Aircraft (STA) operations are especially vulnerable to bird collisions because of the speed and angle of approach to the runway. The high-hazard areas will be the focus of the discussion of the temporal, spatial, and diurnal patterns in avian activity.

Minimizing aircraft operations during seasonal and diurnal peaks in avian activity may be the best approach to reducing the potential of BASH. Single large birds (i.e., vultures, wading birds, Double-crested Cormorants, and Ospreys) or large flocks of smaller birds (i.e., American Robins, swallows, and shorebirds) seem to be the greatest threat to aircraft traveling through high-hazard airspace. Unfortunately, low diurnal activity periods for species such as vultures and wading birds do not coincide. Early morning hours (ca. sunrise to one hour later) are peak activity periods for wading birds traveling from roost sites to foraging grounds. Several hours after sunrise (seasonally dependent) are peak activity periods for vultures within the high-hazard areas. At these times, vultures are leaving their roosts to form foraging flocks. The first two hours after sunrise from March to October may be the most effective time to alter aircraft

operations in an attempt to minimize BASH during that time of year. Attempts to minimize BASH birds from November to February will be more problematic owing to the high variability in diurnal avian activity and in seasonal abundance of birds at this. Bird activity is also weather dependent. Unfortunately birds, like aircraft pilots, prefer good weather.

Spatial variation along the runway depicts the south high-hazard area to have a much greater level of avian activity, both diurnally and seasonally. The abundance of birds in the south high-hazard area can be attributed to Banana Creek and the adjacent impoundments and salt marshes. These habitats are foraging areas for wading birds, shorebirds, gulls and terns, Ospreys, hawks, ducks and swallows. Banana Creek appeared to be a travel route for wading birds foraging within the MINWR. Vultures also roost along the impoundment dike on the south shoreline of Banana Creek. Vultures leave the roost daily to forage, entering the high-hazard airspace in large numbers, three to four hours after sunrise in the summer and four to five hours after sunrise in the winter. Roost site deterrents have been used in the past with limited success. Habitat management to provide adequate roost sites in other locations may be necessary to entice vultures to other roost sites. Further studies of vulture populations on the KSC may also provide a better understanding of roost site selection and preference.

Bird activity and abundance is greatest surrounding the SLF in winter months, from November to February. Over-wintering species and migrants are abundant in the coastal areas of east-central Florida. Large flocks of swallows and American Robins were seen during the winter months with little predictability of location or time of day. Frequently, the activities of these flocks are dynamic and the times in which they are within the high-hazard airspace are brief. Because avian activity is so difficult to predict in the winter, field teams (i.e., Bird Watch Spotters) may be an essential component to communicating avian activity during aircraft

operations from the months of November to February. Bird Watch Spotters could be positioned to view the high-hazard regions during training operations. These individuals could then be used to communicate unsafe conditions within the airspace quickly and efficiently. Bird Watch Spotters would be especially beneficial during migration periods when large flocks are moving around the SLF. To the extent practical, aircraft operations and training procedures should be modified to minimize airspace usage when large mass bird species are most frequent and abundant. The presence of large flocks of smaller birds around the SLF will have to be detected by Bird Watch Spotters and communicated to astronauts and other pilots conducting aircraft operations.

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| 13. ABSTRACT (Maximum 200 words) Spatial and temporal patterns in bird abundance within the five-mile airspace at the Shuttle Landing Facility (SLF) on John F. Kennedy Space Center (KSC), Florida, USA were investigated for purposes of quantifying Bird Aircraft Strike Hazards (BASH). The airspace is surrounded by the Merritt Island National Wildlife Refuge (MINWR) which provides habitat for approximately 331 resident and migratory bird species. Avionic operations shared airspace with 74 bird species during the period from February 1993- January 1994. Red-winged Blackbirds, Boat-tailed Grackles, Cattle Egrets, and White Ibis were common year round in the habitats surrounding the runway. Potential bird strike hazards were greatest around sunrise and sunset for most avian taxonomic groups, including wading birds, most raptors, pelicans, gulls/terns, shorebirds, and passerines. Turkey Vultures and Black Vultures were identified as a primary threat to aircraft operations and were represented in 33% of the samples. Diurnal vulture activity varied seasonally with the development of air thermals in the airspace surrounding the SLF. Variation in the presence and abundance of migratory species was shown for American Robins, swallows, and several species of shorebirds. Analyses of bird activities provides for planning of avionics operations during periods of low-risk and allows for risk minimization measures during periods of high-risk. | | | | | |
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